Azerbaijan State Oil And İndustry University

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- **Group**– 332.24E
- **Work**– Determination of the heat of neutralization of a strong base with a strong acid
- **Subject**– Basics of chemical thermodynamics
- **Instructor**– Valiyeva Asmar

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1. Theorethical Basis

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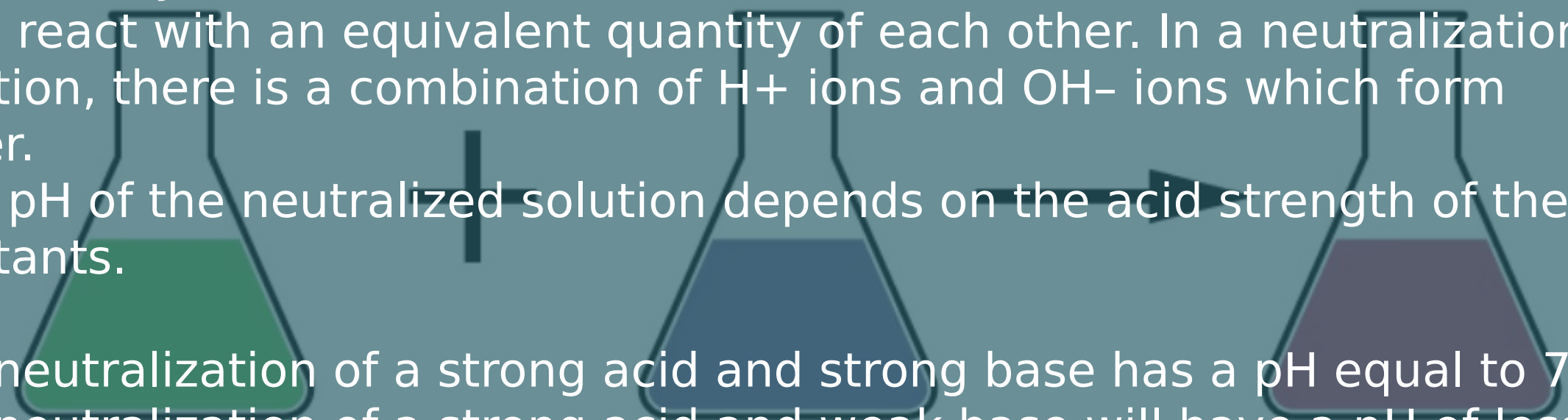
1.1. Neutralization Reaction

In chemistry, neutralization is a chemical reaction in which acid and a base react with an equivalent quantity of each other. In a neutralization reaction, there is a combination of H+ ions and OH– ions which form water.

The pH of the neutralized solution depends on the acid strength of the reactants.



The neutralization of a strong acid and strong base has a pH equal to 7. The neutralization of a strong acid and weak base will have a pH of less than 7, and conversely, the resulting pH when a strong base neutralizes a weak acid will be greater than 7.

Equation of this reaction:

acid + base (alkali) → salt + water

Ionic Equation:

HCl + NaOH → NaCl + H2O

$H^+ + Cl^- + Na^+ + OH^- \rightarrow Na^+ + Cl^- + H_2O$

Net ionic equation:

$H^+ + OH^- \rightarrow H_2O$

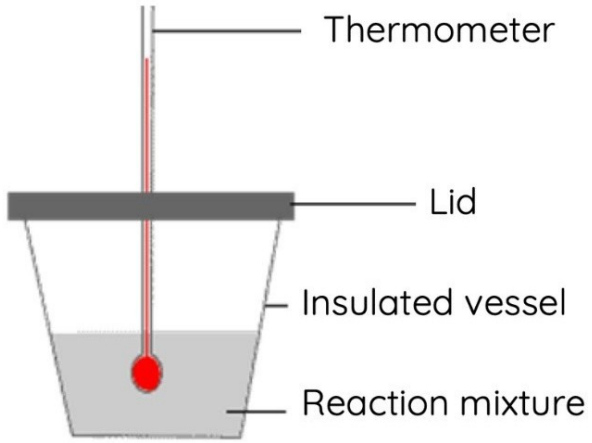
1.2. Heat of Neutraliza

Heat of neutralization (enthalpy of neutralization) is the enthalpy change when one equivalent of an acid and one equivalent of a base react to form water under standard conditions, measured at constant pressure.

Calorimetry

$$q = mc\Delta T$$

$$\Delta H = -\frac{q}{n}$$



For strong acids and strong bases, the value is consistently around −57.3 kJ/mol (or −57 kJ/mol to −58 kJ/mol) because the reaction is always just

$$H^+ + OH^- \rightarrow H_2O.$$

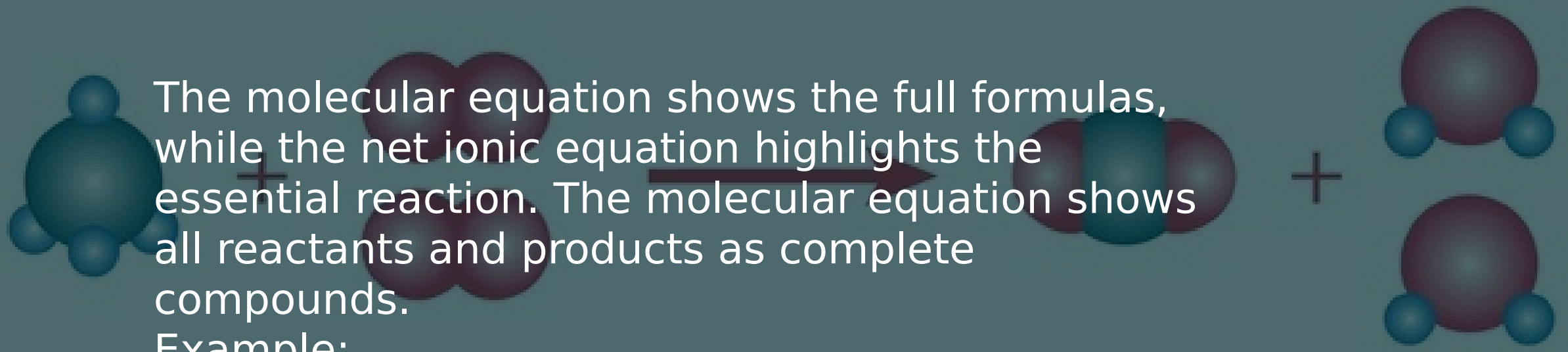
For weak acids + strong bases and strong acid +weak base ΔH < –57 kJ/mol (less heat released)

Why less heat? Because some energy is used to ionize the weak acid first.

Heat of neutralization is measured using a calorimeter.

2. Reaction Equation

2.1. Molecular Equation



The molecular equation shows the full formulas, while the net ionic equation highlights the essential reaction. The molecular equation shows all reactants and products as complete compounds.
Example:

HCl (aq) + NaOH (aq) → NaCl (aq) + H_2O

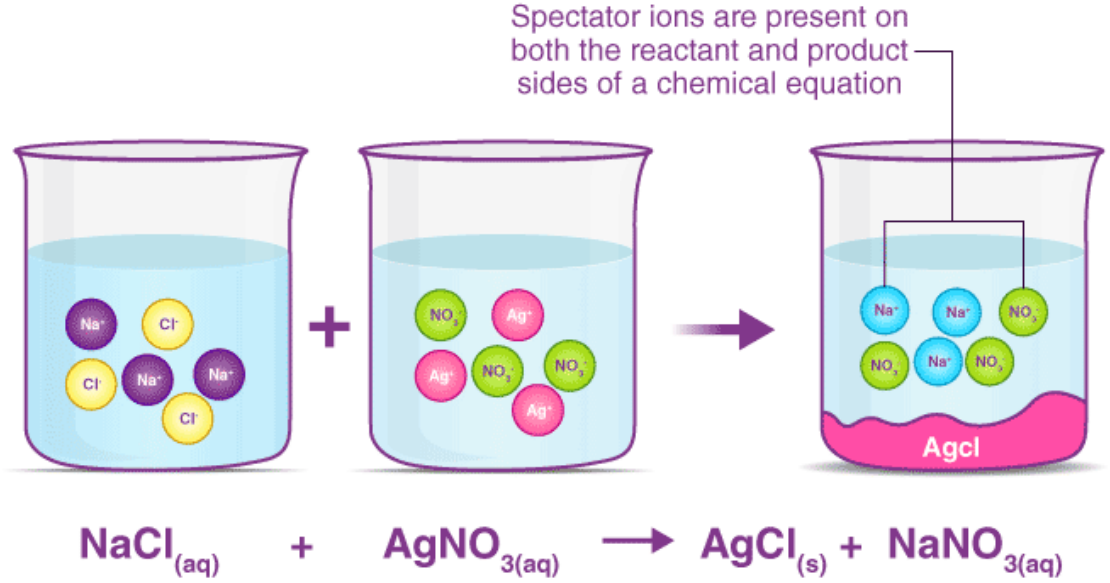
This shows the substances as we normally write them.

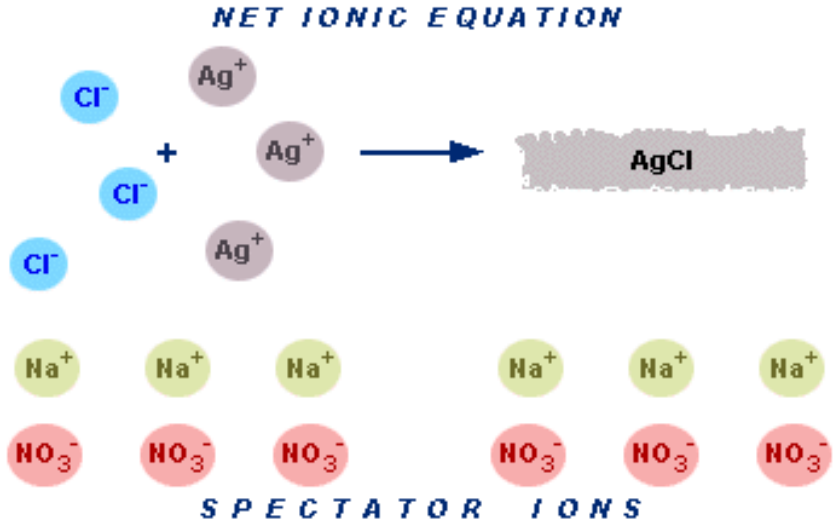
2.2. İonic Equation

In complete ionic equation, all strong electrolytes (strong acids, strong bases, soluble salts) are written as separate ions.

$H^+ (aq) + Cl^- (aq) + Na^+ (aq) + OH^- (aq) \rightarrow Na^+ (aq) + Cl^- (aq) + H_2O$

And then, in net ionic equation we cancel the spectator ions (ions that appear on both sides and do not participate in the reaction)- H^+

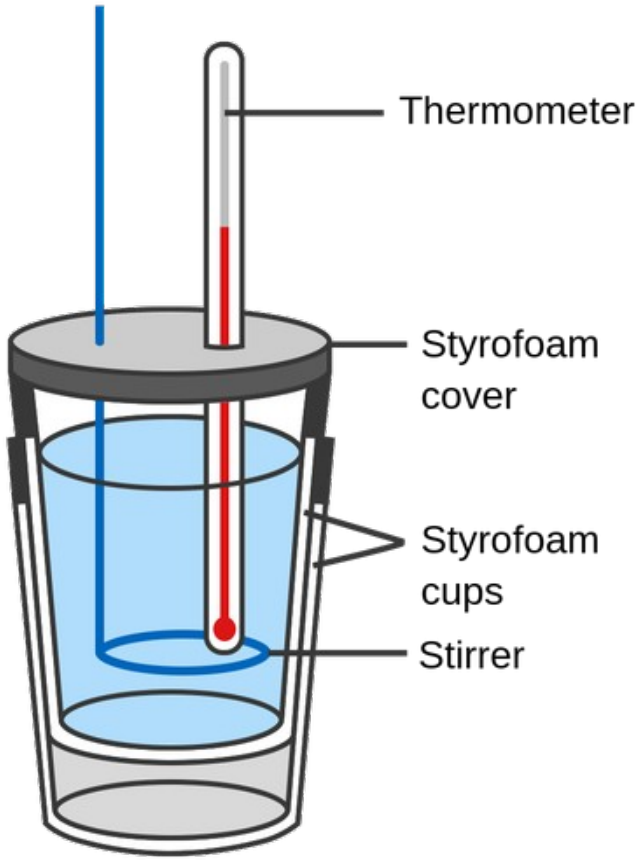

Spectator ions are present on both the reactant and product sides of a chemical equation
Agcl
NaCl(aq) + AgNO3(aq) → AgCl(s) + NaNO3(aq)



4. Experimental Setup

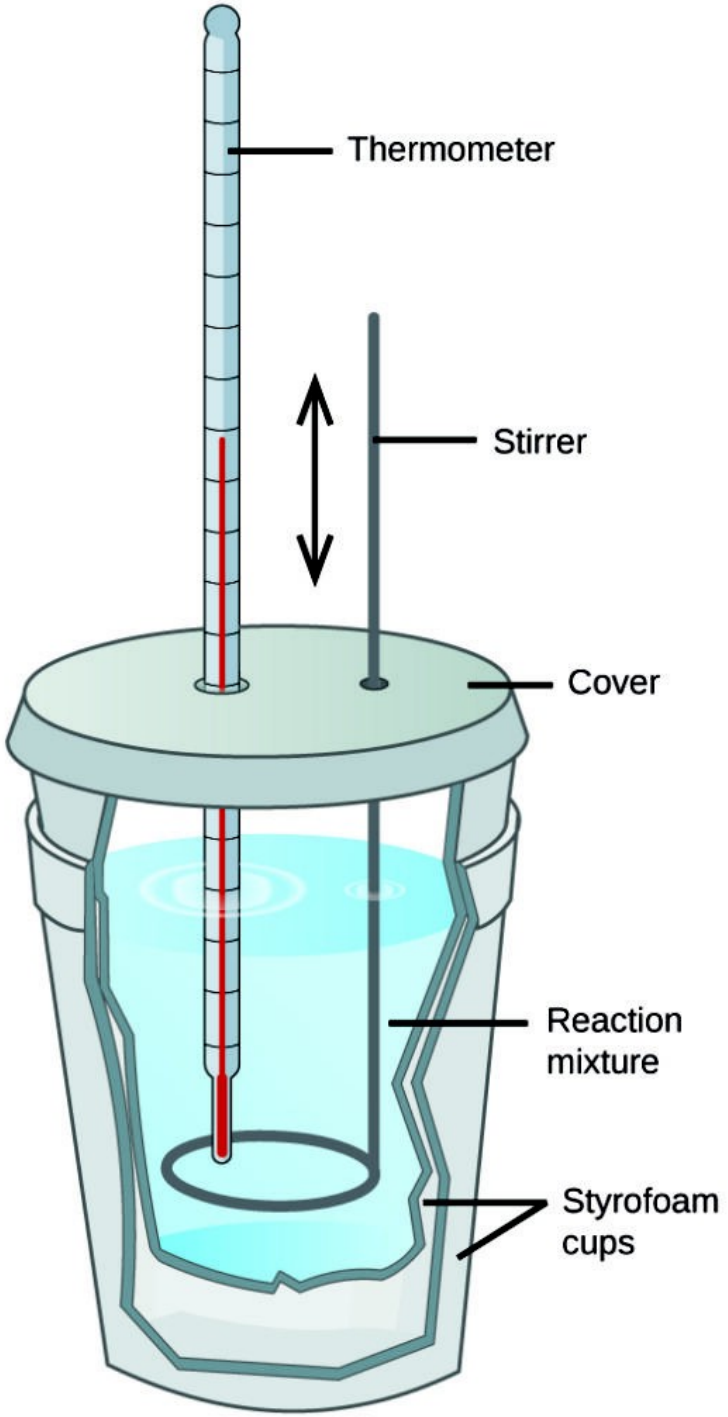
4.1. Outer container

- The outer container is the external supporting vessel that surrounds the calorimetric cup. It is usually: A beaker, plastic container or protective casing.
- It reduces heat loss to the environment, protect against drafts and room temperature fluctuations. Creates an additional barrier between the reaction system and the surroundings. Its materials usually are glass (beaker), hard plastic, sometimes foam insulated casing



4.2. İnner calorimetric cu

- The inner calorimetric cup is where the reaction actually occurs. Usually made of Styrofoam (polystyrene foam) or another highly insulating material. Often two cups are nested together for better insulation. It contains reactants, holds the solution whose temperature change is measured. It minimizes heat capacity error, improves experimental accuracy.



4.3. Thermometer

The thermometer is inserted through the calorimeter lid and measures the temperature change during the neutralization reaction.

- Precision: ±0.1 °C
- Records temperature at 1-minute intervals
- Critical for determining ΔT

Since heat is calculated from temperature change, even small measurement errors directly affect ΔH.

4.4. Stirrer

The stirrer ensures homogeneous mixing of the reacting solutions.

- Prevents temperature gradients
- Maintains uniform heat distribution
- Improves experimental accuracy

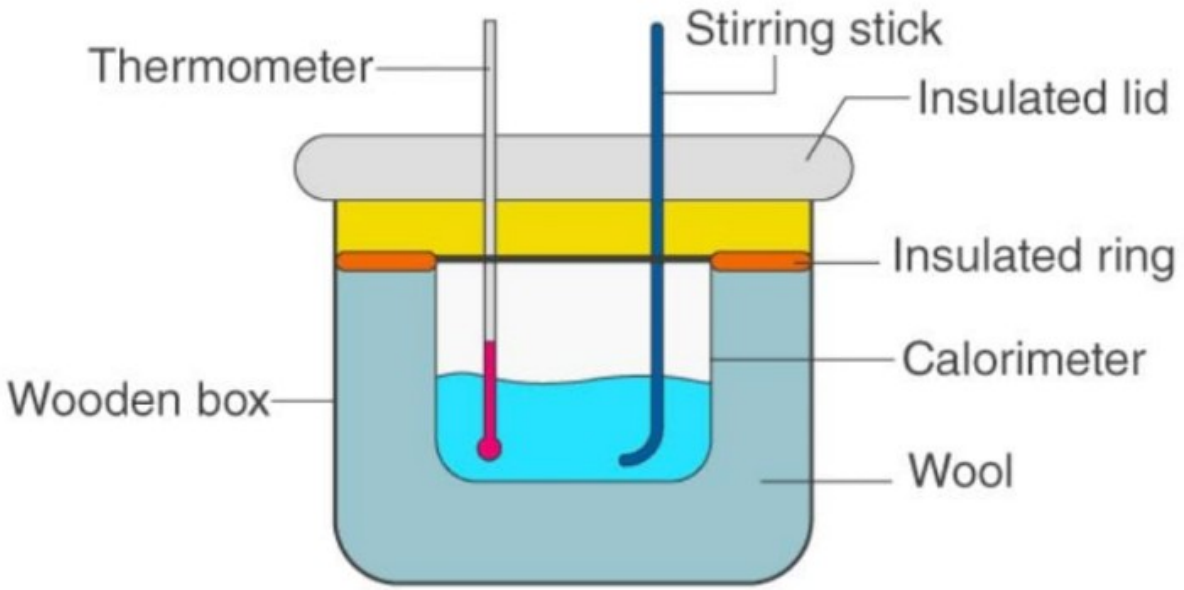
Without stirring, local overheating may cause incorrect ΔT values.

4.5. Funnel

The funnel allows controlled and rapid addition of acid into the calorimeter.

- Minimizes heat loss
- Prevents splashing
- Maintains closed system conditions

This ensures that the heat released is transferred efficiently to the calorimetric system.



5. Experimental Procedure

All experiments aimed at determining the thermal effects of chemical processes must be performed following the same procedure.
First, pour 300 mL of 0.1 N NaOH solution into the reaction vessel. Switch on the stirrer and allow the calorimeter temperature to equilibrate with the surrounding environment. Wait approximately 3–5 minutes before beginning measurements. Then record the thermometer readings every 1 minute for a period of 5–8 minutes.
Once you confirm that the temperature remains constant or changes uniformly, add an equivalent amount of 4 N HCl solution (7.5 mL). While continuously stirring the mixture, measure and record the temperature every 1 minute, monitoring both the increase and the subsequent decrease in temperature.

6. Calculations
6.1. Heat Absorbed by Calorimeter

To determine the amount of heat released during the neutralization of **HCl and NaOH**, we first calculate how much heat is absorbed by the reaction mixture (the solution in the calorimeter). This heat comes from the **neutralization reaction between hydrochloric acid (HCl) and sodium hydroxide (NaOH)**, which causes the temperature of the solution to rise.

The relationship that links heat to temperature change is given by the calorimetry equation:

Where:

- **q** is the heat absorbed by the solution (in joules),
- **m** is the mass of the solution (in grams),
- **c** is the specific heat capacity of the solution (in J g^{-1} $°C^{-1}$), and
- **ΔT** is the change in temperature of the solution (Final Temp − Initial Temp)

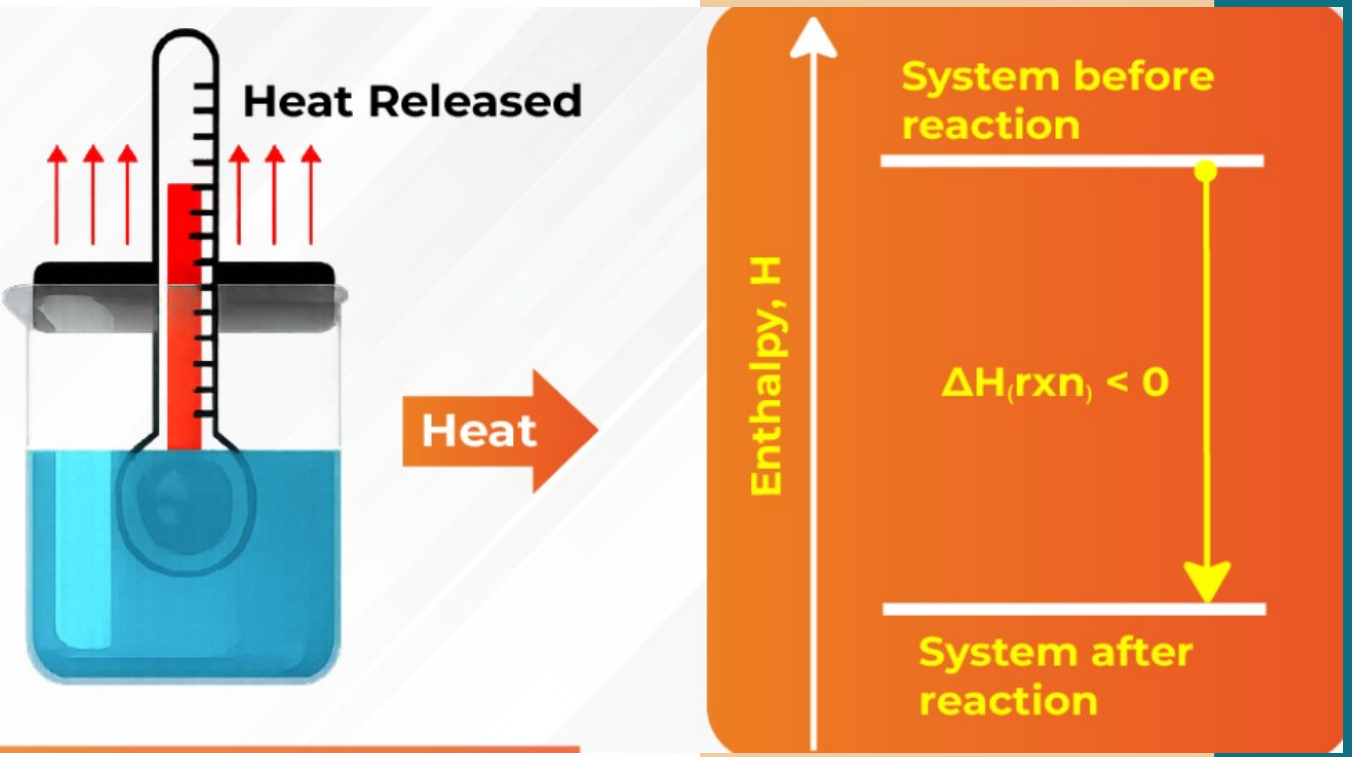
6.2. Determination of ΔH per Mole

The enthalpy change of neutralization (ΔH) for the reaction between **hydrochloric acid (HCl)** and **sodium hydroxide (NaOH)** can be calculated using the heat absorbed by the solution in the calorimeter.

The heat released by the reaction is equal in magnitude but opposite in sign to the heat absorbed by the solution:

Firstly, to determine ΔH per mole we first determine how many moles of water were produced during the reaction. The **moles of water** formed in the reaction are determined from the **limiting reactant** (usually the smaller amount in moles of HCl or NaOH):

where
- **n** is the number of moles,
- **C** is the molar concentration (in mol/L),
- **V** is the volume (in L).



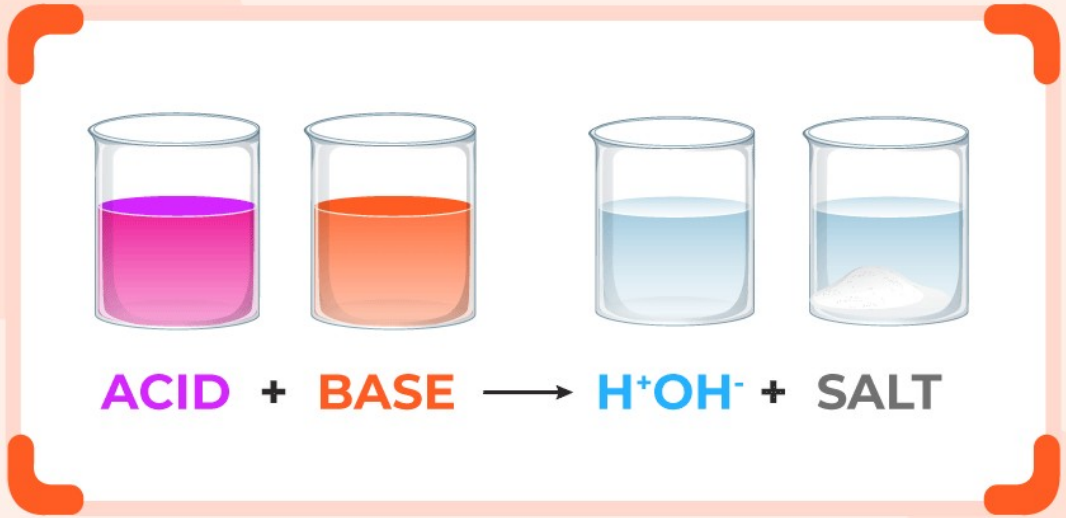
Since the reaction between hydrochloric acid (HCl) and sodium hydroxide (NaOH) proceeds in a **1:1 mole ratio** and produces one mole of water for each mole of acid and base reacted, the moles of water formed are equal to the number of moles of reactants used.

Finally, the enthalpy change of neutralization is calculated using:

Here, **ΔH** is the enthalpy change per mole of water formed, **q** is the heat released during the reaction, and **n** is the number of moles of water.

This value is given in **kJ/mol** and is negative because the process is **exothermic** — meaning heat is released during the reaction.

7. Conclusion



The experiment showed that the neutralization reaction between HCl and NaOH is exothermic, meaning that heat is released during the reaction(22 C-25C).

The theoretical enthalpy change for the neutralization of a strong acid with a strong base is approximately:

The experimental enthalpy change ($\Delta H = -126\,kJ/mol$) is greater in magnitude than the theoretical value ($\Delta H \approx -56\,kJ/mol$). This means the reaction released more heat in the experiment than expected.
The experiment also proved the effectiveness of calorimetry in measuring energy changes in chemical reactions. Additionally, it provided important insights into understanding the exothermic and endothermic nature of chemical

THANKS FOR YOUR ATTENTION!